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Livermore, California

PROGRAM UPDATE - MAY 2002

LS&T

Laser Science & Technology

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Short-Pulse, High-Average-Power Laser System for Micromachining

Under a work-for-others contract, LS&T is developing a 100-W-class psec, kHz, solid-state laser system for rapid, precision machining of 100-µm-scale features in metals and alloys. This advanced laser drilling (ALD) system has recently been assembled and has undergone initial testing. It delivered, for material processing application, over 50 W in a 2-psec, 4-kHz pulse train to the workpiece.

This short-pulse, high-average-power laser employs numerous advanced laser technologies of the LS&T program. These technologies include a solid-state regenerative amplifier and a power amplifier using diode-pumped Yb:YAG as gain medium and a high-power multilayer dielectric grating. A simplified schematic of this laser is shown in Figure 1. The laser system architecture is based on chirped-pulse amplification (CPA). It starts with a mode-locked Yb-doped fiber laser, which was developed by Imra Corporation specifically for this application. This mode-locked oscillator produces a 4-kHz train of 8-psec, chirped pulses with an average power of 120 mW (2.4 nJ/pulse at 50 MHz). The spectral bandwidth of the oscillator pulses is 2 nm. The psec pulses from the fiber oscillator are stretched in time to 4 nsec using a diffraction grating pulse stretcher, amplified by 75 dB, then recompressed to 2-psec duration before being sent to the target chamber. Between each of these laser subsystems, computer-based pointing and centering loops are used to precisely control laser beam alignment.

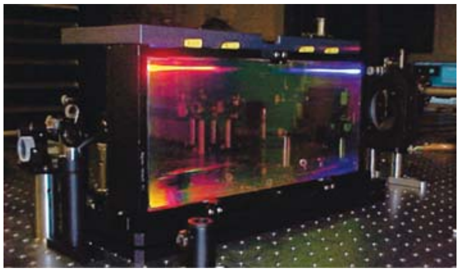

Figure 2. The large dielectric diffraction grating for the ALD laser has a diffraction efficiency of 97% and an rms wavefront of 1/40th of a wave averaged over the surface.

The stretching-and-compressing process that is the basis of the CPA architecture is accomplished by using a high-efficiency dielectric diffraction grating (see Figure 2) manufactured by LS&T's Diffractive Optics Group. This large (150 × 335 mm) multilayer dielectric grating has a diffraction efficiency of >97% at 1030 nm. Whereas a typical CPA-based laser system architecture may use 4 diffraction gratings (2 for the stretcher and 2 for the compressor), the current design employs a single grating that is shared by both the stretcher and compressor. This single-grating stretcher/compressor design enabled the combination of two laser subsystems in a compact unit that can readily be incorporated into a hardened system that can withstand the harsh conditions on the factory floor.

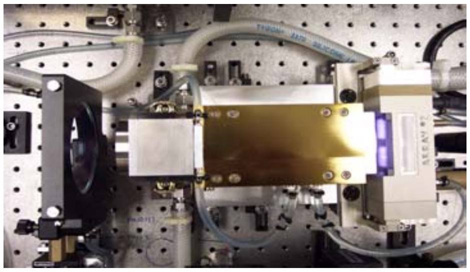

Figure 3. The Yb-YAG amplifier uses LS&T technologies: tapered Yb-YAG rods with heat-diffusing end caps; hollow lens duct; repass pump mirrors; and a water-cooled jacket for the rod.

The 75 dB of amplification between the pulse stretcher and compressor is accomplished by two subsystems: a linear-cavity regenerative amplifier (regen) and a power amplifier. Both amplifiers use Yb:YAG as the gain medium, pumped with micro-channel-cooled diode laser arrays (operated at 940 nm). The regen amplifies the 1-nJ stretched-pulses up to 750 µJ and converts the pulsing frequency from 50 MHz to 4 kHz (using a Pockels cell). The power amplifier has two heads. It boosts the regen output from 3 W to 50 W in two passes. With the use of a grating compressor, the pulse width of the amplified beam from the power amplifier is compressed from 2 ns back to 2 psec, multiplying the laser peak power by a factor of a thousand. We developed special water-cooled housings for the amplifier rods to efficiently dissipate heat and minimize amplified stimulated emission and parasitic losses in the laser cavity. The Yb-doped rods are also tapered to minimize parasitic oscillation. Undoped end caps are fused onto the end of each amplifier rod to minimize thermal gradients on the rods. A water-cooled hollow lens duct with precisely machined inner surfaces is used to efficiently couple pump light into the laser rods. Figure 3 shows the power amplifier assembly.

For material processing, the output from the compressor is delivered directly to the workpiece in the target chamber. We have made good progress in the machining of ~100-µm features in metals and alloys as required by our industrial partner. We plan to transfer this high-average-power, solid-state laser technology to our industrial partner for applications in manufacturing.

—J. Crane, G. Huete, L. Shah, M. Shirk, B. Stuart, and S. Telford

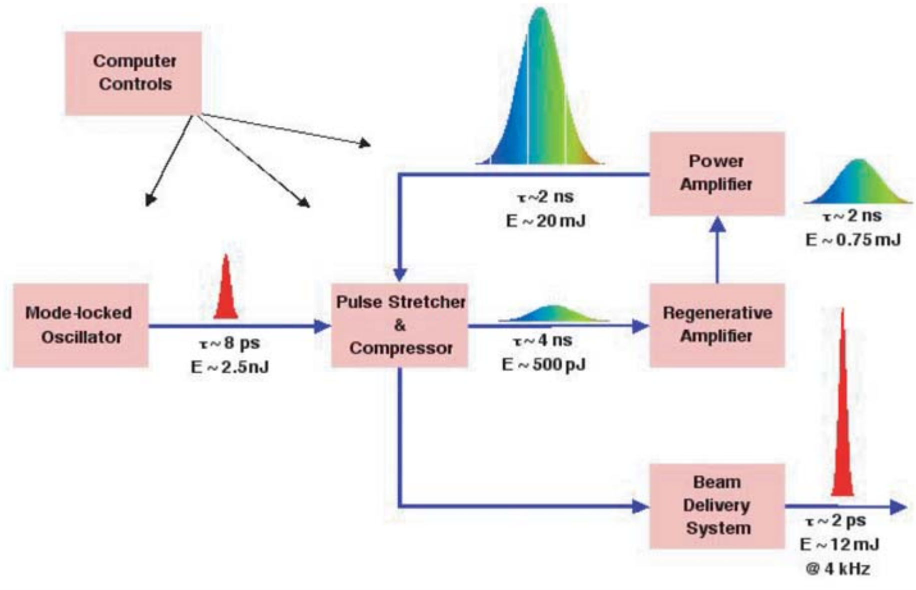

Figure 1. Laser system architecture uses chirped-pulse amplification to produce mJ-level short-pulse output.

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To get on the mailing list of the *LS&T Program Update*, send a request to Frances Mendieta, mendieta1@llnl.gov
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